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SMALL WATERPLANE AREA TWIN HULL (SWATH) COMBATANT SHIP PARAMETR--ETC(U)
SEP 78 C G KENNELL, T A ANDERSON
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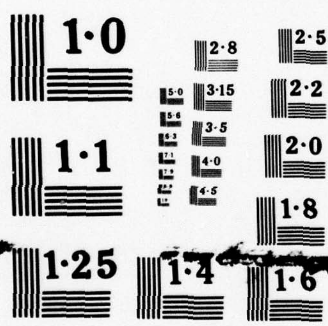

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COMBATANT SHIP PARAMETRIC STUDY.

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Teresa A./Anderson

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This study defines the anticipated size and speed of SWATH escort ships. The study baseline assumes conventional state-of-the-art materials, subsystems, design philosophy, and operational practices. Double reduction gear and planetary gear transmission systems were included with prime movers in the hulls. Conventional geared electric, right angle drive, and cryogenic systems with turbines in the box or cross-structure were also studied. Installed powers of 45,000 SHP (2 LM 2500s), 70,000 SHP (2 FT9s), 90,000 (2 LM 5000s or 4

Item 20.(Continued)

LM 2500s), 140,000 SHP (4 FT 9s) and 180,000 SHP (4 LM 5000s) were studied. In addition, the sensitivity of the results to assumptions made in the study was examined.

The study results show that current technology SWATH escort ships will displace 5,000 to 8,000 tons. Sustained speeds of these ships will be about 25 knots. Speeds of 30 knots or better are possible by combining a right angle drive or cryogenic transmission system with increased installed horsepower. Increased ship sizes accompany these increased speeds. Smaller ships and higher speeds are possible by using all aluminum structure, reducing crew size, or changing mission elements such as range and endurance speed. Such changes will require strong endorsement by the operational community.

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Raymond Savoie, NAVSEC 6112

Herbert Farrington, NAVSEC 6152

Paul Friedman, NAVSEC 6144

Robert Lamb, DTNSRDC 117

Lynn Parnell, NOSC 631

The authors would like to acknowledge both the quality of the contributed work and the enthusiastic cooperation of these professionals.

TABLE OF CONTENTS

List of Figures

List of Tables

Section 1

INTRODUCTION

This study was requested by Dr. David Mann, Assistant Secretary of the Navy (Research, Engineering, and Systems) in a 1 June 1978 Memorandum to the Chief of Naval Material. This memorandum and other project correspondence can be found in Appendix D.[1/] The technical analysis was completed and a presentation of study results was briefed to Mr. Gerald Cann, Deputy Assistant Secretary of the Navy (Systems) on 11 August 1978.

This study was conducted to quantify the effects of various types of propulsion plant concepts and other key parameters on the size and speed of Small Waterplane Area Twin Hull (SWATH) ships. Combatant ships in the 2,000 to 8,000 ton size range with speeds between 25 and 35 knots were studied.

Section 2 of this report discusses the methods used to conduct this study. The third section presents baseline results for ships using current technology. The fourth section addresses the impact of advanced transmission systems on the baseline ships. Next, the effects of increasing installed power are covered. The sixth section discusses the sensitivity of the study results to a number of assumptions implicit in the study. Finally, overall study results are discussed and summarized.

This work was requested by NAVSEA Work Request WR 8G097 Amendment No. 7. NAVSEC JON 328TC02 was assigned to the task.

1/ - Appendices will be distributed separately.

Section 2

STUDY METHODOLOGY

The purpose of this study was to quantify parametric relationships between payload, speed, and size of SWATH ships. The role of several developmental propulsion system types in attaining speeds of 25 to 35 knots for escort missions was studied. Parametric curves of payload weight versus ship size, sustained speed versus ship size, and related cross-plots have been developed.

A study of this scope is influenced by a large number of variables. Some of these variables, such as endurance speed, manning philosophy, maintenance philosophy, and payload characteristics are operational "requirements." Others, such as habitability standards, margins, arrangement, and subsystem types are design "options." Relationships between these variables must be established to assure consistent results in the study. Only in this way can the effects of variations in individual parameters be rationally examined. The validity of any parametric study is tied to this underlying web of inter-relationships.

NAVSEC's SWATH Synthesis Model was used extensively to assure consistency in many of the engineering aspects of the problem. The synthesis model approach allowed the same algorithms to be used to estimate weights for auxiliary systems (e.g., air conditioning, heating, ship control), outfit and furnishing (e.g., deck coverings, furniture), and stores for all ships in the study. Structures were designed for all ships using common criteria and philosophy. Electrical requirements for all ships reflect the same assumptions. Ship drag and fuel loads were calculated assuming the same efficiencies. Also, common margins were used for all ships.

Relationships used in parametric models of propulsion plant characteristics were developed by using NAVSEC's SWATH Propulsion Plant Design Computer Program (Appendix A) for a range of ship sizes.

Some of the more complex relationships evolve from the amount and type of payload to be carried by a ship. Payload includes armament, electronics, aircraft, ammunition, aviation fuel, and related spare parts and stores. Linear relationships were derived (Appendix B) that allow payload to be described by two numbers; payload weight in tons and payload density in pounds per cubic foot. With these relationships, each combination of weight and density can be resolved into a specific weight distribution for the above mentioned payload items. In addition, specific payload area and volume requirements can be derived for box (cross-structure), superstructure, and hangar. Furthermore, a specific ship's complement can be derived.

While functional relationships can be derived from existing data for many aspects of SWATH ship design, the available data are inadequate in some areas to specify values for parameters. In particular, a coherent, integrated process has not yet evolved to specify, *a priori*, those hull form parameters that will allow a particular SWATH ship to realize its potential as a superior seakeeping platform with improved operational effectiveness. Hull form parameters in this case refers to those geometrical and mass property characteristics (length, prismatic coefficient, waterplane area, metacentric heights, etc.) which determine the ship's dynamic behavior and usefulness. After the first few dozen SWATH ships have put to sea, hindsight will undoubtedly make the selection of these parameters seem trivial.

The approach taken for this study was to synthesize a series of hull form guidelines (Appendix C) from existing analytical and experimental data. This process relied on the intuitive insight of experts in the SWATH technical community. Some of the guidelines, such as those for prismatic coefficient, waterplane area coefficient and transverse metacentric height were followed closely since this was compatible with the tools available for the study. Other guidelines, such as those for waterplane area, longitudinal metacentric height, and length-diameter ratio followed less closely. Rigid adherence to these guidelines would have required time-consuming program coding changes which were prohibited by the schedule. This approach is justified because the guidelines are recommendations and not hard requirements. Also, in a real design, subsystem limitations such as the limiting hull diameter and strut thickness required for machinery may prohibit ideal forms. Furthermore, the parametric nature of the overall study injects a range of values into the study for any unconstrained variables. The degree to which these guidelines have been followed can be assessed by comparing the characteristics of the ships in the study with the recommended guidelines (See Appendix C). In this manner, many "good" SWATH hull forms were generated for the study. While not minimum resistance forms, or optimum seakeeping forms, the several hundred ships in this study are <u>all</u> representative of good design practice for potential SWATH combatants.

SWATH hulls are generally separated into two groups, single strut (one strut per hull) and multistrut (two struts per hull). The design of a multistrut SWATH ship with satisfactory powering characteristics is more complicated and time consuming than a similar single strut SWATH ship due to the greater number of geometrical variables. Also, the capability to rapidly produce the large numbers of multistrut designs necessary for a study of this type does not exist. Furthermore, it is NAVSEC's judgement that the number of struts on a SWATH hull does not significantly affect the size, cost, or performance of a SWATH ship. For these reasons, the basis of this study was the single strut form. Multistrut forms were treated as a hull parameter in the sensitivity study area to establish a bound for this aspect of the SWATH design problem.

Limiting dimensions for strut thickness and hull diameter were determined by developing machinery arrangement drawings for all possible combinations of the numbers of turbines, types of turbines, and transmission types listed in Table 1.

Table 1. MACHINERY PLANT OPTIONS

No of Turbines	Turbines	Transmission
2	LM 2500	Double Reduction Gear
4	FT 9	Planetary Gear
	LM 5000	Geared Electric
		Right Angle Drive
		Cryogenic

A separate NAVSEC report is planned for FY 79 to document the assumptions, approach, and results of this SWATH machinery arrangement study. A sample machinery sketch, machinery weights, and limiting hull and strut dimensions are included in Appendix A.

From a production standpoint, the study reduced to exercising the NAVSEC synthesis model while observing all guidelines and limitations judiciously. The result of this process was several hundred SWATH point designs and a twelve foot stack of computer paper.

Section 3

CURRENT TECHNOLOGY BASELINE

The first step in a parametric study is to develop baseline data which then serve as a benchmark for comparing other data. Since interest in this study centered on SWATH escort ships, the baseline mission characteristics are similar to those of current monohull frigates and destroyers. Table 2 lists certain key baseline parameters.

Table 2. BASELINE PARAMETERS

Payload	200-600 Tons
Payload Density	5.5 - 9.0 lbs/cu.ft.
Range	4500 miles @ 20 Knots
Endurance	45 Days
Installed Power	45,000 SHP
Machinery	(2) LM 2500 Gas Turbines Double Reduction Gear CRP Propeller
Complement	Conventional Manning Practice

An understanding of payload weight and payload density is fundamental to this study and warrants elaboration. Payload weight is the weight of armament, electronics, aircraft, ammunition, aircraft fuel, and related spares and stores. As points of reference, FFG 7 payload carries 340 tons of payload while DD 963 carries 643 tons.

Payload density is payload weight in pounds divided by the total enclosed volume in cubic feet associated with armament systems, electronics systems, aircraft hangar and shops, magazines, fuel tanks, offices, and storerooms. The lower density (5.5 lb/cu.ft.) represents an aviation dominated payload with only those electronic systems necessary to operate the ship and aircraft in the open ocean. The high density payload (9.0 lb/cu.ft.) assumes the payload consists of gun and missile systems with extensive surveillance and fire control electronics. Payload density is 7.4 lbs/cu.ft. for FFG 7 and 9.1 lbs/cu.ft. for DD 963.

The numerical density values associated with the different payload types reflect current warship philosophy. In particular, weapon system/electronic system, launcher/ammunition, and aircraft/fuel/ordnance relationships are typical of current ships. Obviously, the density of a heavily aviation oriented payload can be drastically altered by doubling

the amount of aviation fuel. However, the study results would not be significantly affected since proper handling of such an atypical aircraft/ fuel ratio would not significantly alter the important parameters such as the required hangar and shop volumes, the arrangement of the ship, and the crew size.

Crew size in the baseline ships reflects conventional Navy manning practices. For the payload parameters investigated, crew size varies from 284 men on a 200 ton payload high density (gun and missile) ship to 403 men on a 600 ton payload low density (aviation) ship.

The LM 2500/Double Reduction Gear/CRP propeller propulsion plant was selected for the baseline because all components are current state-of-the-art.

In short, the mission, design philosophy, and all subsystems of the baseline ships are the same as those used in todays monohull combatants. The only difference is the use of the SWATH hull form.

The results for this current technology baseline are shown in Figure 1. The lower curves show payload weight as a function of full load displacement for three different payload densities. The upper plot shows sustained speed of the baseline ships versus full load displacement.

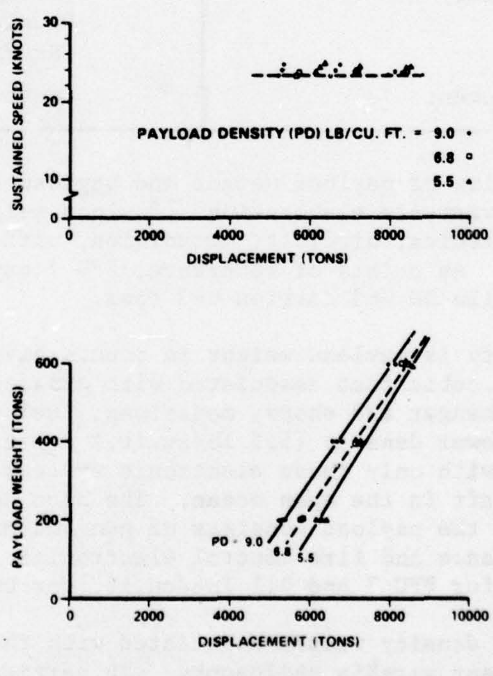


Figure 1.
SWATH SHIP BASELINE 45,000 SHP (2-LM2500) – DOUBLE REDUCTION GEAR

Full load displacement is the displacement of a fully loaded ship ready for battle. Sustained speed is a ship's maximum speed in service with a foul bottom and in rough water.

The plots show that a SWATH escort employing current technology and practices will displace 5,000 to 8,000 tons and will have a sustained speed of about 25 knots.

The Payload Weight-Displacement plot indicates that varying the nature of the payload from low density (aviation) to high density (guns and missiles) reduces ship size by roughly 700 tons. A one ton change in payload weight changes displacement by almost seven tons.

The sustained speed-displacement plot shows that speed is rather insensitive to displacement changes in this size range. A brief explanation is in order since this behavior is not what the reader might expect and it occurs in most of the speed plots that follow. The upper curve in Figure 2 shows that the residual resistance (principally wavemaking) of the baseline ships decreases sharply as ship size increases from 5,000 tons to 8,000 tons.

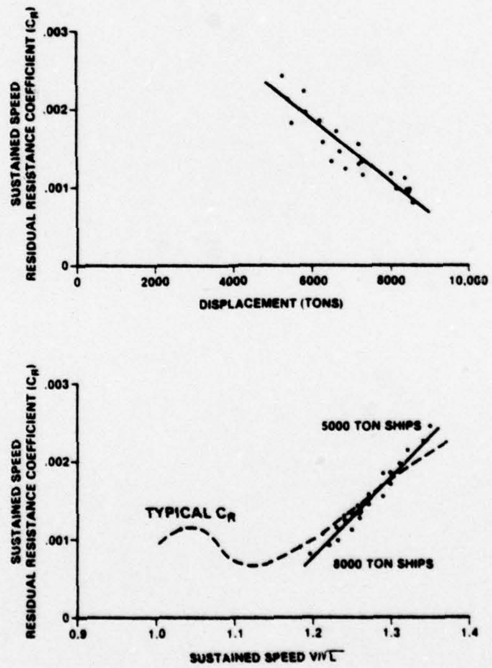


Figure 2.
SUSTAINED SPEED C_R FOR BASELINE SHIP 45,000 SHP (2-LM2500) –DOUBLE REDUCTION GEAR

This strong gradient offsets the effects of increased wetted surface that accompanies increased ship size. This causes the drag of ships in this size range to be roughly constant. Hence, the flat speed curve in Figure 1.

The lower curve in Figure 2 provides further amplification by superimposing the sustained speed, C_R, data for the baseline ships on a typical residual resistance coefficient versus speed-length ratio curve (dashed curve) for SWATH ships. Since larger ships are generally longer ships, a large ship has a lower speed-length ratio than a small ship at the same speed. Hence, the slope of the data in the upper curve in Figure 2, and consequently the flat speed curve in Figure 1, is due to the characteristics of SWATH drag curves.

The data shown in Figure 1 demonstrate the effect of payload density on the baseline. The following curves will all assume a medium payload density of 6.8 lbs/cu.ft. The dashed curve (6.8 lbs/cu.ft.) on the baseline payload weight-displacement plot will be repeated on many of the following plots to serve as a benchmark. Also, the corresponding sustained speed curve (dashed curve in speed plot) will be repeated as a reference aid.

Section 4

TRANSMISSION SYSTEM ALTERNATIVES

The systems shown in Table 3 are included in this study as alternatives to the current technology double reduction gear transmission.

Table 3. ALTERNATIVE TRANSMISSION SYSTEMS

- Planetary Gear
- Geared Electric - high speed conventional electric motors and double reduction gear
- Right Angle Drive - mechanical ZEE drive and planetary gear
- Cryogenic Drive

These systems reduce the hull diameter and/or strut thickness required to arrange propulsion machinery in a SWATH hull form. Figure 3 illustrates the magnitude of these effects for the transmission systems included in this study.

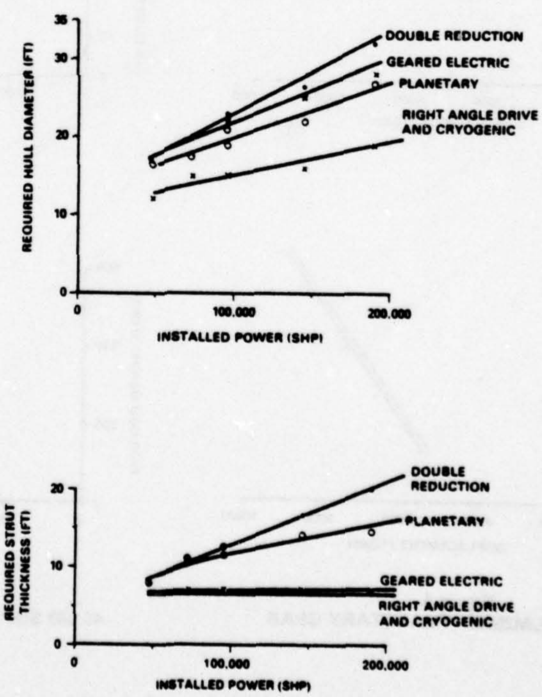


Figure 3.
MACHINERY PLANT CONSTRAINTS

As the minimum acceptable hull and strut dimensions are reduced, a much wider range of hull/strut configurations can be considered for a given design. This increases the likelihood that the desired performance characteristics can be achieved. It is apparent that this problem becomes acute when attempting to squeeze large amounts of power into small platforms.

Figures 4 through 7 show the effects on ship displacement and sustained speed of planetary gears, geared electric, right angle drive, and cryogenic drive respectively. Again, the dashed lines in the figures represent the double reduction gear baseline.

Interestingly, those transmission systems requiring the gas turbine to be located in the box or cross structure (i.e., geared electric, right angle drive, and cryogenic) cause an increase in ship size of several hundred tons. The use of these transmission systems does not change speed significantly.

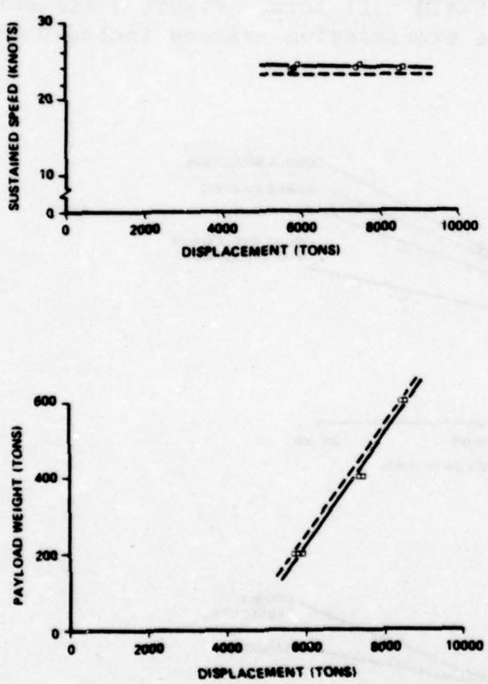


Figure 4.
45,000 SHP (2-LM2500) – PLANETARY GEAR

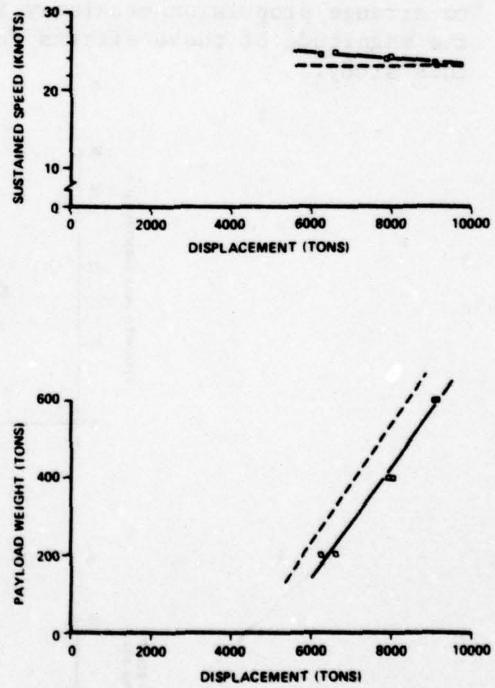


Figure 5.
45,000 SHP (2-LM25000) – GEARED ELECTRIC

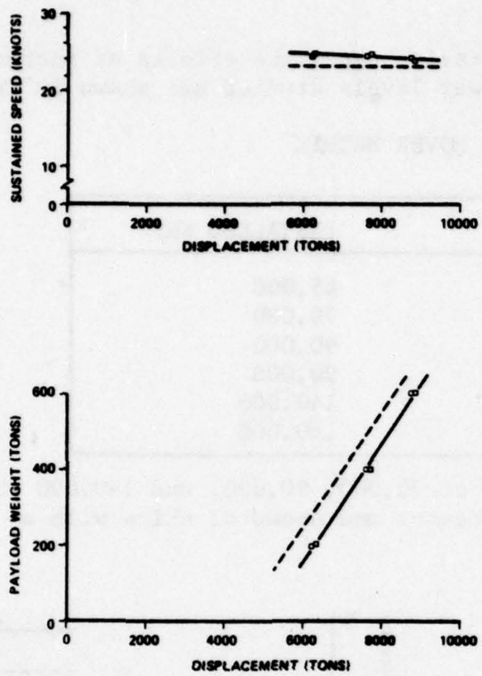


FIGURE 6.
45,000 SHP (2-LM2500) – RIGHT ANGLE DRIVE

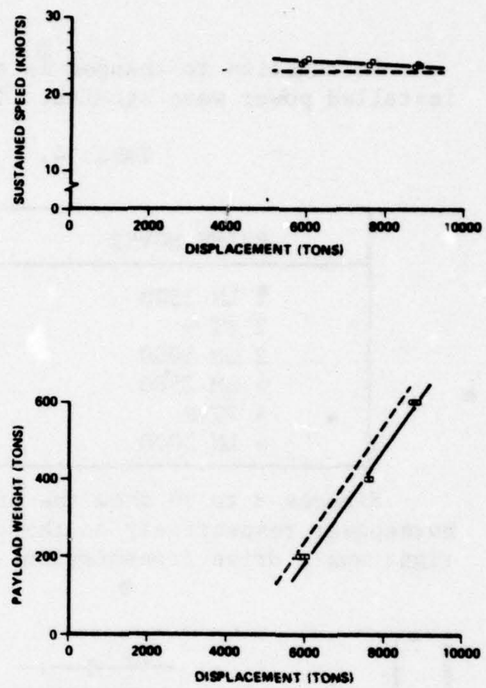


Figure 7.
45,000 SHP (2-LM2500) – CRYOGENIC TRANSMISSION

The underlying reason for the increased displacement associated with top side turbine designs is the added box volume required to install the turbines, gears, generators, etc. These systems are located in the hulls for double reduction and planetary gear ships. The added hull and strut volume available in topside turbine designs cannot be used because of its dimensions and location. The differences between the three topside arrangement curves is due to differences in machinery plant weight and the reduced fuel rate which results from the ability of the electric plants to power both propellers with one gas turbine (cross connected).

The modest impact of these alternative transmission systems on sustained speed is traceable to the geometric realities of this size of ship and the amount of power in question. A balanced design satisifying the baseline requirements (mission, payload, crew, etc.) results in a ship which accommodates all the 45,000 SHP propulsion plants comfortably. As a consequence, an alternative transmission alone will not significantly affect speed at this power level and ship size.

Section 5

VARIATION OF INSTALLED POWER

In addition to changes in transmission type, the effects of increasing installed power were studied. The power levels studied are shown in Table 4.

Table 4. PRIME MOVER MATRIX

PRIME MOVER	INSTALLED SHP
2 LM 2500	45,000
2 FT 9	70,000
2 LM 5000	90,000
4 LM 2500	90,000
4 FT 9	140,000
4 LM 5000	180,000

Figures 8 to 10 show the effects of 70,000, 90,000, and 140,000 shaft horsepower respectively on the displacement and speed of ships with a right angle drive transmission.

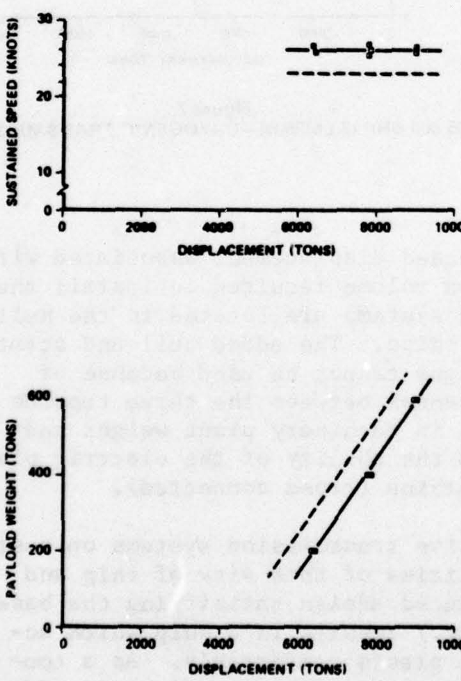


Figure 8.
70,000 SHP (2-FT9) – RIGHT ANGLE DRIVE

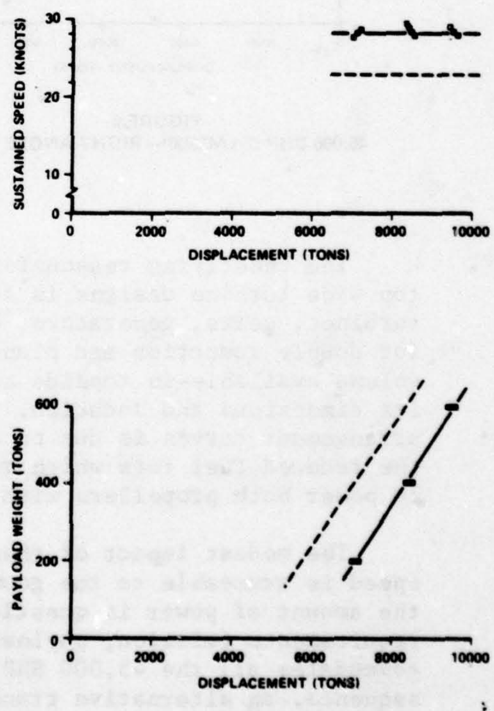


Figure 9.
90,000 SHP (4-LM2500) – RIGHT ANGLE DRIVE

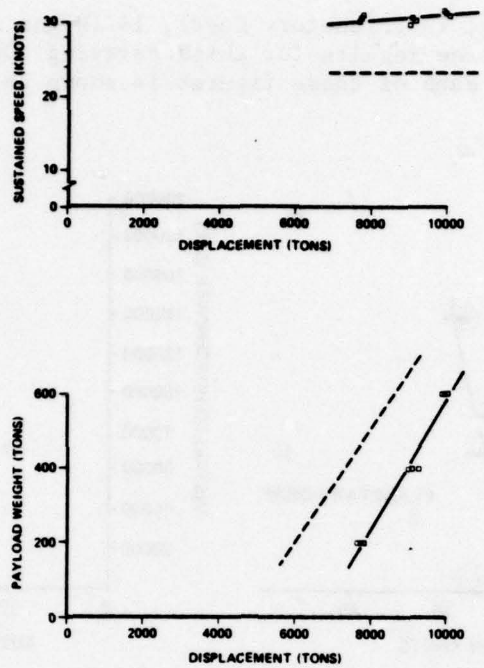


Figure 10.
140,000 SHP (4-FT9) – RIGHT ANGLE DRIVE

Similar data were developed for each transmission type.

More interesting are the cross-plots of sustained speed versus installed power that can be obtained from such data. Figures 11 (Double Reduction Gear),

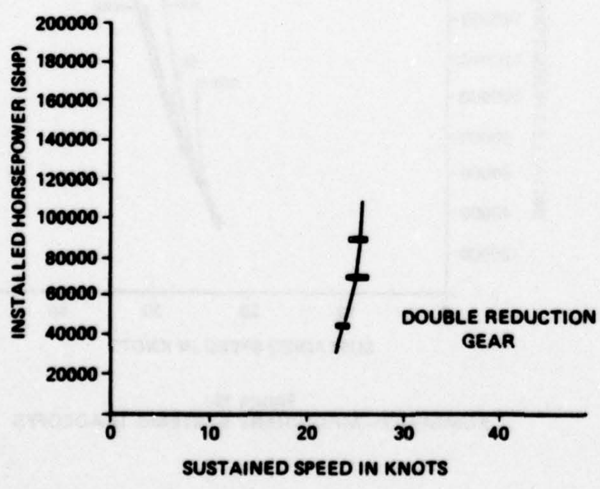


Figure 11.
CROSS PLOT OF SPEED VS POWER

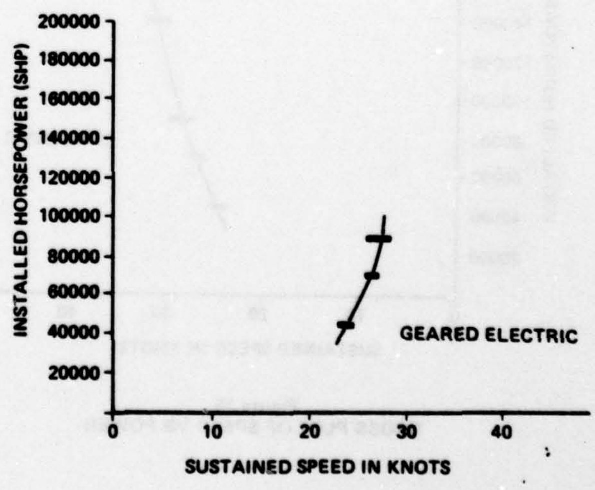


Figure 12.
CROSS PLOT OF SPEED VS POWER

12 (Geared Electric), 13 (Planetary Gear), 14 (Right Angle Drive), and 15 (Cryogenic) show the results for ships carrying 400 ton of payload. The trend line from each of these figures is shown on the summary plot, Figure 16.

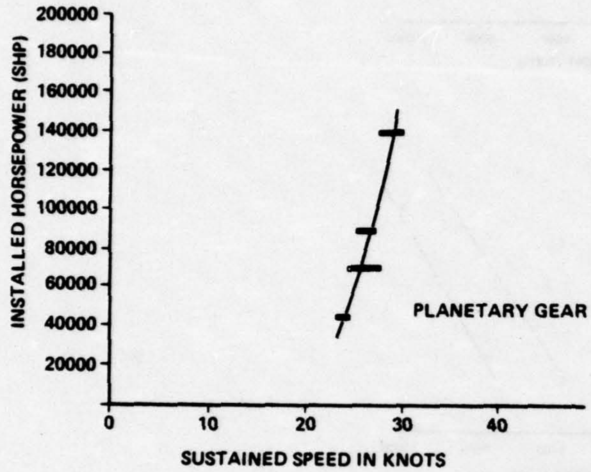


Figure 13.
CROSS PLOT OF SPEED VS POWER

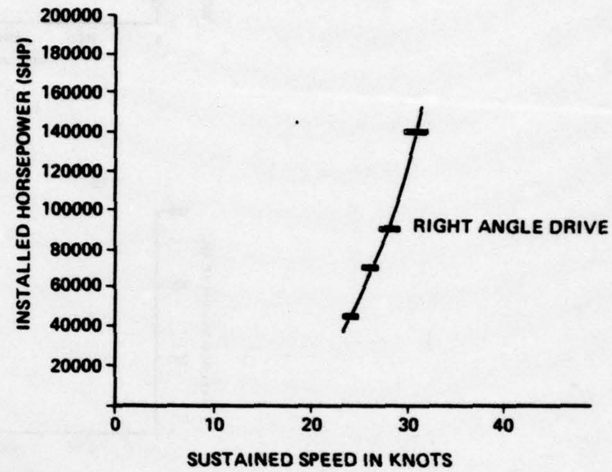


Figure 14.
CROSS PLOT OF SPEED VS POWER

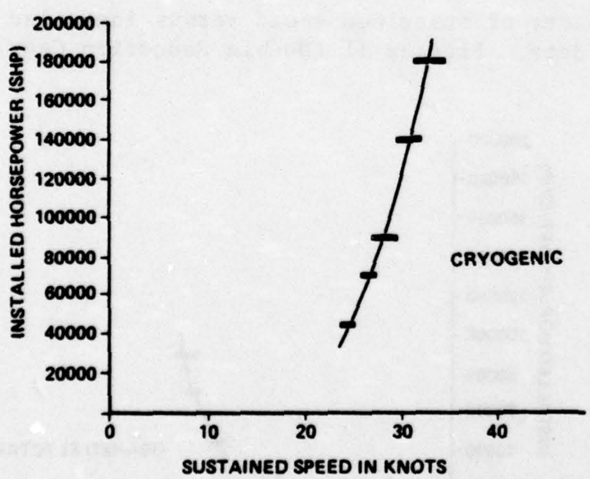


Figure 15.
CROSS PLOT OF SPEED VS POWER

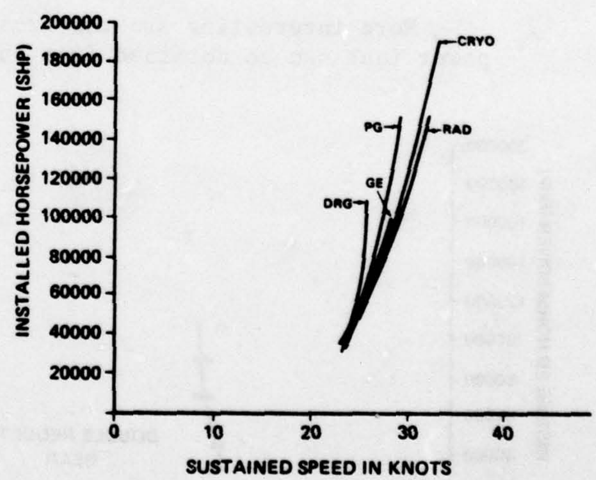


Figure 16.
SUMMARY – MACHINERY SYSTEMS TRADEOFFS

Several of the curves are truncated at power levels well below 180,000 SHP, the maximum installed power included in this study. These cut-off points are determined by the geometric limitations of the different propulsion plant schemes. As an extreme example, a 180,000 SHP double reduction gear ship requires a 32 foot diameter hull and a 20 foot thick strut. Achieving such dimensions would result in a displacement exceeding 20,000 tons, well outside the size range of interest in this study.

From these figures, it is clear that SWATH escort ships can achieve sustained speeds in excess of 30 knots by installing over 120,000 shaft horsepower with a right angle drive or cryogenic transmission. None of the installed power/transmission system combinations studied provided 35 knot capability. The faster ones would make 35 knots trial speed.

The difference between sustained speed (shown in all previous plots) and trial speed should be clarified. Sustained speed is the maximum speed a ship can maintain in rough water with a foul bottom while trial speed is a ships maximum speed in calm water with a clean bottom. Sustained speed is representative of a ships actual long-term operational speed capability. Figure 17 shows sustained and trial speeds versus installed power for right angle drive ships carrying 400 tons of payload. This typical plot indicates that trial speeds are roughly 1-3 knots faster than sustained speeds for the ships in this study, depending on the installed power and drag characteristics of the ship in question.

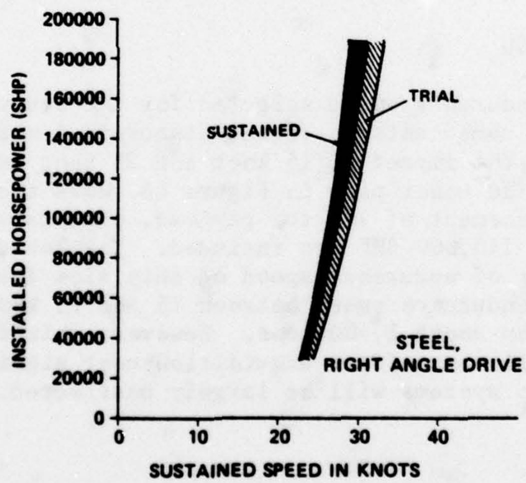


Figure 17.
TRIAL SPEED VICE SUSTAINED SPEED

Section 6

SENSITIVITY STUDIES

The goal of a parametric study is to quantify the effects of varying the independent variables one at a time. Necessarily, this assumes constant values for all other independent variables. The sensitivity of the results to the assumed values for these other independent variables must be determined to insure that conclusions are not compromised by rational variations in these independent parameters.

In modeling a system as complex as a naval combatant, there is a vast number of assumptions buried in every design. Schedule and common sense prohibited examination of all such parameters. Table 5 lists those parameters which were examined.

Table 5. SENSITIVITY STUDIES

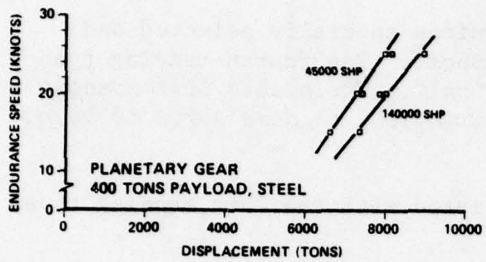
• Endurance Speed	• Structure
• Range	• Hull Parameters
• Manning	• Box Inner Bottom

6.1 ENDURANCE SPEED

The 20 knot endurance speed selected for the study is characteristic of all major naval combatants in recent history. A series of ships was designed to assess the impact of 15 knot and 25 knot endurance speeds on displacement. The upper plot in Figure 18 shows the impact of endurance speed on the displacement of 400 ton payload, planetary gear ships. Data for 45,000 SHP and 140,000 SHP are included. The lower plot in Figure 18 shows the effect of endurance speed on ship size for different payload weights. Varying endurance speed between 15 and 25 knots changes full load displacement by about 1,500 tons. However, this change is largely one of fuel, and will not effect acquisition cost significantly since most essential ship systems will be largely unaffected.

6.2 RANGE

Similar results are achieved by varying range about the 4,500 mile baseline. Figure 19 shows that changing range from 6,000 miles to 3,000 miles reduces ship size by about 1,100 tons for 45,000 SHP right angle drive ships. This sizeable change in displacement is again accompanied by marginal changes in sustained speed. The lower plot on Figure 19 also shows the effect of range on light ship displacement, i.e., displacement of a ship with fuel, ammunition, aircraft, crew, provisions, and stores



VARIATION OF ENDURANCE-SPEED-BASELINE

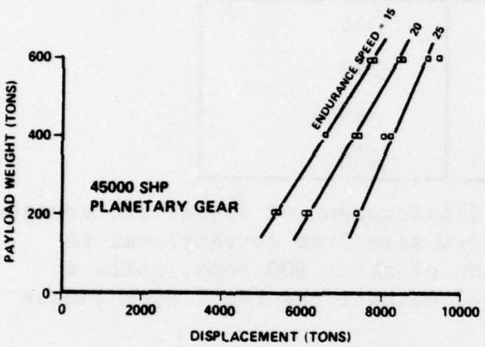
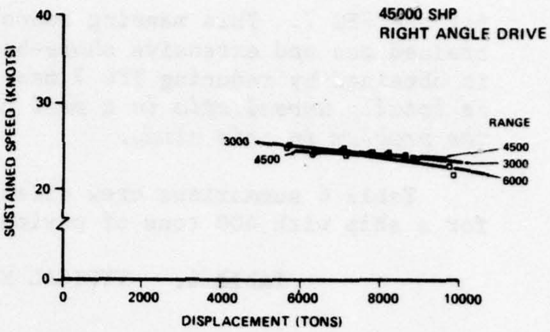


Figure 18.
VARIATION OF ENDURANCE SPEED



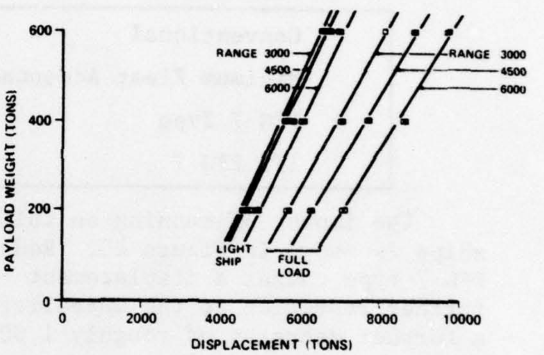


Figure 19.
RANGE VARIATION

removed. The change in lightship displacement is less than one half the change in full load displacement for a given range variation.

6.3 MANNING

While the implications of changes in range and endurance speed are simple to grasp, variations in manning are somewhat more involved. Crew sizes on the baseline ships have been selected to reflect current fleet manning practices, maintenance philosophy, and operational practices. Proposing alternative numbers of crew for the purposes of this study is a relatively simple matter. However, ascertaining whether a given number of men can operate and maintain a ship, estimating the amount of shore-based support required, and predicting the cost of different manning philosophies is well beyond the scope of this study.

Without entering the debate about which manning philosophy should be adopted, four manning level concepts have been used to check the sensitivity of the study results to variations in this important parameter. The first is the conventional manning baseline used throughout the study. Derived crew sizes are a known quantity in terms of what the men can do, how well they can do it, and how much they cost. The second type of manning is based on the NAVSEC estimate of the minimum crew size acceptable to the fleet. The third type of manning is similar to the manning philosophy

for the FFG 7. This manning concept requires specially selected and trained men and extensive shore-based support. The fourth manning type is obtained by reducing FFG 7 manning by half. *While this last concept is totally unrealistic in a real world situation, it does serve to bound the problem in this study.*

Table 6 summarizes crew sizes associated with the four manning types for a ship with 400 tons of payload.

Table 6. TYPICAL MANNING - 400 TONS PAYLOAD

Conventional	344
Minimum Fleet Acceptable	293
FFG 7 Type	248
1/2 FFG 7	124

The impact of manning on full load displacement of 45,000 SHP cryogenic ships is shown in Figure 20. Reducing crew size from conventional to FFG 7 type causes a displacement reduction of about 800 tons, while a further reduction to the unrealistic level of half the FFG 7 type causes a further decrease of roughly 1,000 tons.

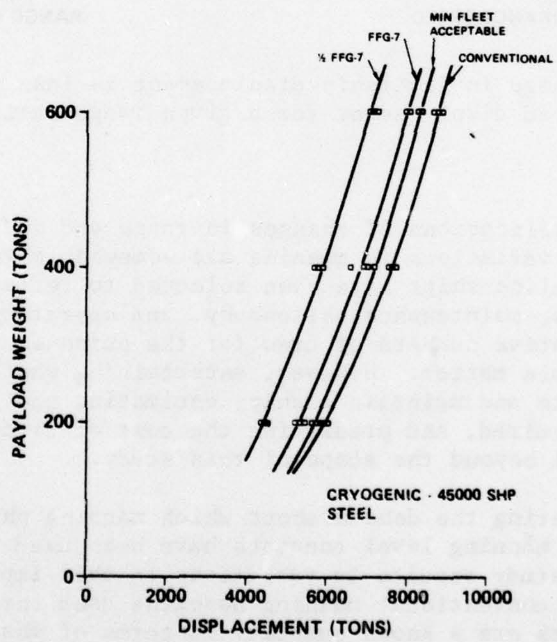


Figure 20.
VARIATION OF MANNING LEVELS

6.4 STRUCTURE

The structural weight of a ship is a large fraction of the total ship weight. As a result, reducing structural weight by a given percentage has a large effect on ship size. Two types of structural weight reduction were investigated in this study, aluminum structure and refined steel structure.

A major problem associated with aluminum primary structure is its vulnerability to fire, a not infrequent hazard on warships. To overcome this limitation, a weight allowance of one pound for each square foot of internal, above waterline, primary structure surface was included to represent passive fire protection materials.

Figure 21 shows the results of using aluminum structure on 45,000 SHP right angle drive ships. Again, only a slight speed improvement results from a sizeable displacement reduction. In addition to the baseline curve, a curve for steel right angle drive ships is shown on the payload weight versus displacement plot. Aluminum structure will reduce full load displacement by about 1,500 tons in this size range.

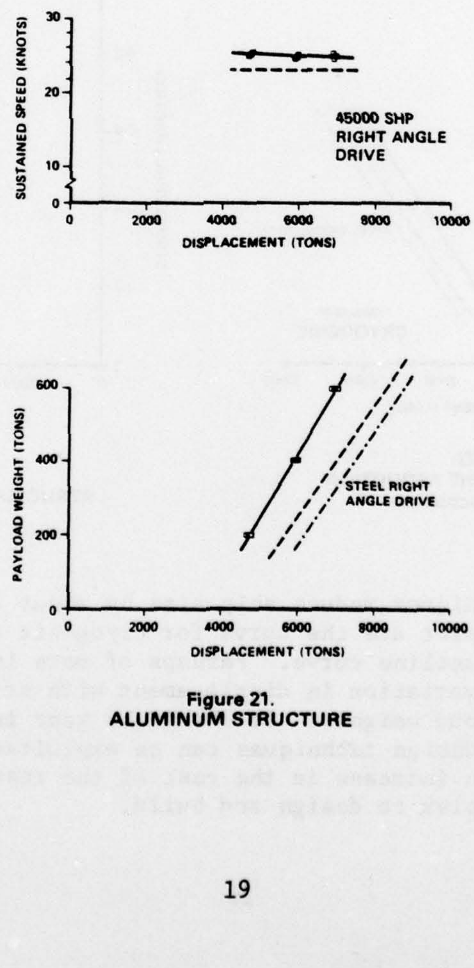


Figure 21.
ALUMINUM STRUCTURE

The weight associated with steel structure can vary considerably through the selective use of high strength steels (HY 80, HY 100, etc.) and the manipulation of structural design details such as stiffener spacing and the use of intermediate lateral supports. Rather than attempt to address the structural design possibilities in detail, the approach adopted for this study was to bound the problem by considering the percentage reduction in structural weight that is possible with steel structure. Past efforts indicate that the weight of structure is reduced less than 20% through the use of refined design techniques. This value was selected as a lower limit. Typical plots of speed and payload weight versus displacement are shown in Figure 22 for a structural factor of 0.80 (i.e., 20% weight reduction) for 45,000 SHP cryogenic drive ships.

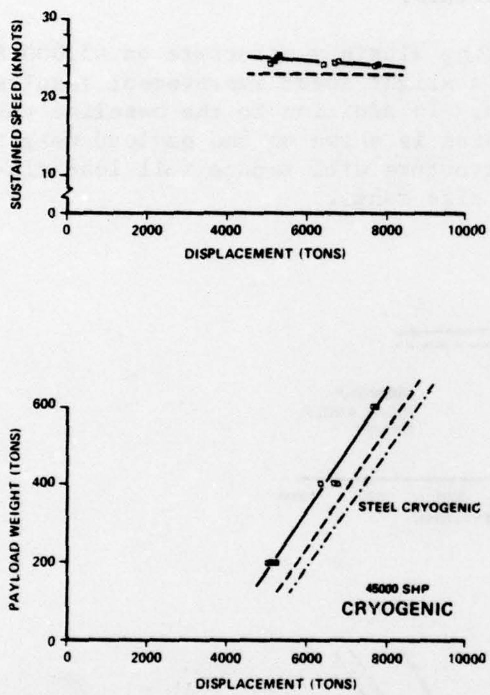


Figure 22.
STRUCTURAL WEIGHT REDUCTION
STRUCTURAL FACTOR 0.80

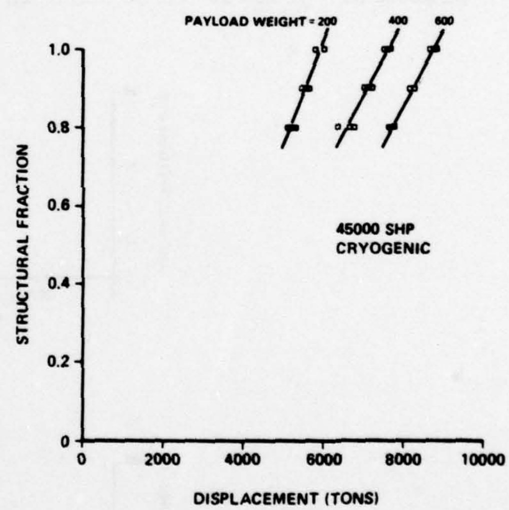


Figure 23.
STRUCTURAL WEIGHT REDUCTION

Refined design techniques reduce ship size by about 1,000 tons. Also shown in the lower plot are the curve for cryogenic ships with conventional suructure and the baseline curve. Perhaps of more interest is Figure 23 which shows the variation in displacement with structural fraction for a range of payload weights. It should be kept in mind that while refined structural design techniques can be exploited to reduce ship size, there may well be an increase in the cost of the resulting structure since it will be more complex to design and build.

6.5 HULL PARAMETERS

The speed of a ship and the amount of fuel it requires to make its range are strongly influenced by the size and shape of its hull. The hull form definition approach taken in this study has been to determine *a priori* values for hull parameters that would result in "good" resistance characteristics. Good refers not to optimum or minimum drag characteristics, but rather to resistance characteristics which are representative of successful balanced designs. Disturbing the balance of a good design by using so called optimum or minimum resistance forms could result in some marginal improvement in speed and ship size at the cost of compromising other features. Only a rigorous design effort of some detail will quantify these effects.

A substantial amount of variation in hull form parameters is possible without resorting to exotic hull forms. The curves in Figure 24 show the variation in speed and displacement as a function of installed power that can be obtained through manipulation of hull form parameters. Ships in these plots have right angle drives and carry 400 tons of payload. For a given installed power, variations in hull parameters can change speed by as much as three knots and displacement by as much as 700 tons.

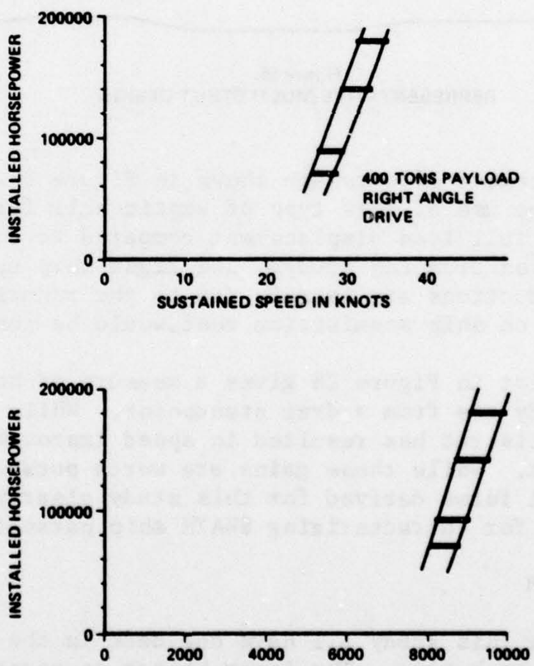


Figure 24.
HULL FORM VARIATIONS

Several designs were prepared by hand to demonstrate the changes in size and speed that result from using exotic hull forms. In these cases, the particular type of hull form chosen was the multistrut form which uses changes in hull shape to reduce wavemaking drag. Figure 25 shows a representative design for a right angle drive ship with 200 tons of payload.

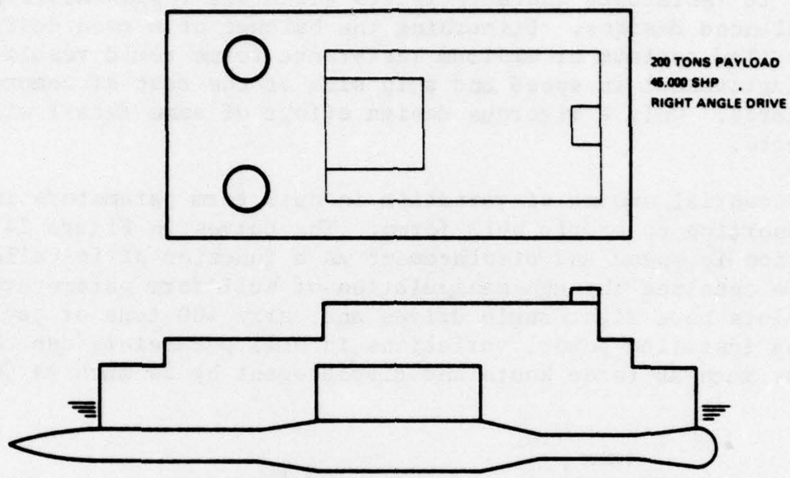


Figure 25.
REPRESENTATIVE MULTI STRUT DESIGN

Speed and displacement effects are shown in Figure 26. The lower plot shows clearly that use of this type of exotic hull form results in a 600 ton reduction in full load displacement compared to corresponding single strut designs taken from the study. The light ship curves indicate that such sizeable reductions are largely due to the reduced fuel load required. Hence the impact on ship acquisition cost would be less significant.

The upper plot in Figure 26 gives a measure of how good the conventional ships in the study are from a drag standpoint. While the special attention given to the multistrut has resulted in speed improvement, the gains are relatively modest. While these gains are worth pursuing in an acquisition process, the hull forms derived for this study clearly reflect good practice and are adequate for characterizing SWATH ship parametric behavior.

6.6 INNER BOTTOM

The ships in this study all have one deck in the box (cross-structure) as well as an inner bottom. The inner bottom increases the strength of the structure, decreases the ships vulnerability to weapons attack and sea damage, and improves the internal arrangement of the ship by providing space for piping, cabling, ducting, and tankage outside the arrangeable spaces. Inner bottoms are recommended for SWATH combatant ships.

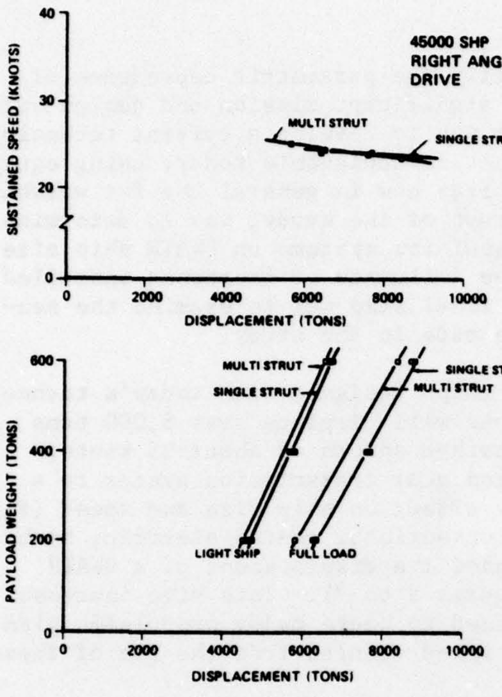


Figure 26.
STRUT VARIATION

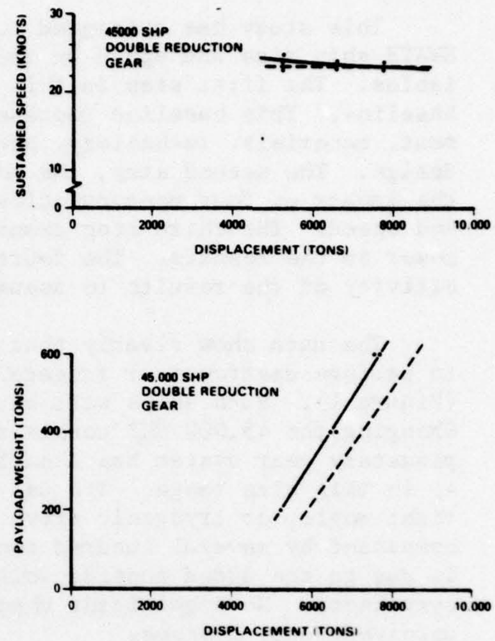


Figure 27.
INNER BOTTOM VARIATION

However, it is possible to design SWATH ships without inner bottoms by utilizing false floors and overhead spaces throughout the box. Figure 27 illustrates the reduction in ship displacement and the impact on sustained speed obtained by designing ships without inner bottoms. Ship size is reduced about 700 tons by eliminating the inner bottom from ships with 45,000 SHP installed and double reduction gears. Speed is unaffected.

Section 7

DISCUSSION

This study has attempted to quantify the parametric dependence of SWATH ship size and speed on the more significant mission and design variables. The first step in this effort was to develop a current technology baseline. This baseline represents what is achievable today, using equipment, materials, technology, and practices now in general use for warship design. The second step, the main thrust of the study, was to determine the impact of four nonconventional propulsion systems on SWATH ship size and speed. The third step examined the influence of increased installed power on the results. The fourth and final step was to examine the sensitivity of the results to assumptions made in the study.

The data show clearly that SWATH ships designed with today's technology to perform destroyer or frigate missions will displace over 5,000 tons (Figure 1). Such ships will have sustained speeds of about 25 knots. Changing the 45,000 SHP double reduction gear transmission system to a planetary gear system has a negligible effect on ship size and speed (Figure 4) in this size range. The use of a conventional geared electric, mechanical right angle, or cryogenic drive increases the displacement of a SWATH combatant by several hundred tons (Figures 5 to 7). This size increase is due to the added topside volume needed to house major propulsion plant components. No significant change in speed results from the use of these unconventional systems.

Increased speeds are possible (Figures 13 to 15) by combining planetary gears, right angle drives, or cryogenic systems with the higher power levels provided by large gas turbines now being developed. Speeds in excess of 30 knots can be reached (Figure 16) with 120,000 installed horsepower and either a right angle drive or cryogenic transmission. Larger ship sizes accompany this increase in speed. The success of such ships will hinge on the development of more powerful gas turbines and CRP propellers capable of transmitting more than 60,000 SHP, as well as the components of the right angle drive (including planetary gears) or the cryogenic drive.

This study produced hundreds of ship designs. A fraction of the data has been presented in the curves included in this report to show typical behavior of the data. It has been shown that variations of the parameters can cause significant changes in ship size and speed. While the parameters have been varied one at a time, the effects of simultaneously varying several of the parameters have not yet been discussed. Figure 28 shows the effects on speed and size of variations in several of the parameters previously discussed for a 45,000 SHP right angle drive ship. Range has been reduced to 1,500 miles at 15 knots. Aluminum structure has been used. Complement has been reduced to half of the FFG 7 types. The payloads have been reduced to the 50 to 200 ton range. While the

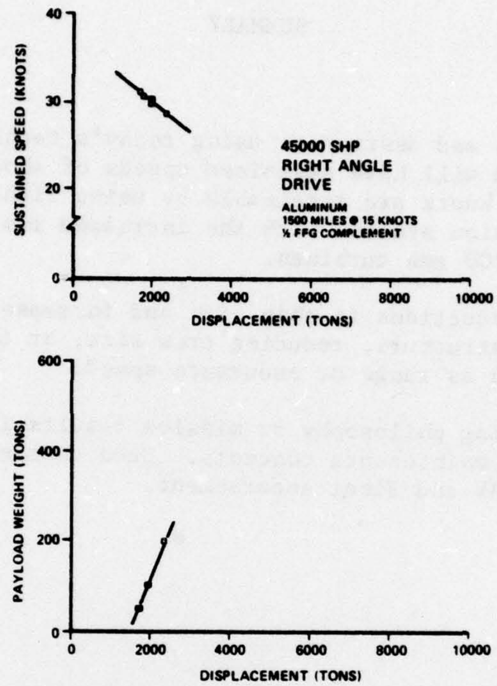


Figure 28.
COMBINED EFFECTS

wisdom of designing ships in such an unrealistic manner should seriously be questioned, the data clearly show marked reductions in ship size and significant increases in sustained speed. Displacements for such "designs" are in the 2,000 ton range compared to the 5,000 to 8,000 ton sizes of most of the realistic escort ships in this study. Sustained speeds of over 30 knots are reached with 45,000 SHP installed compared to the 25 knot speeds of the larger ships. Obviously, if the assumptions are radical enough, small, high speed designs are possible.

Section 8

SUMMARY

SWATH frigates and destroyers using today's technology will displace over 5,000 tons and will have sustained speeds of about 25 knots. Sustained speeds of 30 to 35 knots are attainable by using right angle drive or cryogenic transmission systems with the increased installed power offered by the FT9 or LM 5000 gas turbines.

Significant reductions in ship size and increases in speed are possible by using aluminum structure, reducing crew size, or changing elements in the mission such as range or endurance speed.

Changing manning philosophy or mission results in significant changes in operational and maintenance concepts. Such changes are unrealistic without strong OPNAV and Fleet endorsement.

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